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COMPARATIVE EFFICIENCY OF WIRE-BASKET BUNKERS IN REFRIGERATOR CARS

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THE CAR-COOLING PROBLEM

Refrigerator cars in the fruit and vegetable service to-day are provided with compartments for ice at each end of the car. These compartments are filled through hatches fitted with insulated plugs located at each corner of the roof, and partitions, or bulkheads, separating them from the loading space.

Although the designers of this type of car differ in opinion as to the kind of ice bunker to be installed, all recognize the fact that the cooling of a refrigerator car is entirely dependent upon gravity for the circulation of air within it. This circulation is brought about by the cooling of the air as it comes in contact with the ice. The cooled air slowly drops to the floor of the bunker and issues therefrom into the loading space, where it is brought in contact with the load and again slowly rises as it becomes warmer and passes through and over the load back into the bunker.

Under these conditions the movement of air is exceedingly slow, and in order to accelerate it and to obviate the possibility of any obstruction that would block it great care must be exercised in the construction of the car. To obtain the maximum degree of cooling much attention has been paid to the construction of the ice compartment, or bunker, and in connection with this study consideration has been given also to the insulation of the car, without which the effectiveness of the ice in the bunker would be lost.

Not until the year 1918 was any attempt made to standardize the refrigerator car. In that year, as a result of the efforts of the

United States Department of Agriculture in cooperation with officials of the railroads and refrigerator-car lines and of car builders who were attempting to find the best methods of handling, storing, and shipping fruits and vegetables, the United States Railroad Administration issued recommendations for what is now known as the United States standard refrigerator car.

Most of the refrigerator cars built or rebuilt since this type of car was recommended do not comply with the United States standard specifications in all details, but the essential features—adequate insulation, basket bunkers of sufficient ice capacity to cool the load properly, insulated bulkheads with openings at top and bottom large enough to allow free air movement in and out of the ice compartment, and floor racks of sufficient height from the car floor to allow an easy unrestricted flow of air under the load—are generally recognized by car designers and embodied in their plans.

INSTALLATION OF WIRE-BASKET BUNKERS

The cars of the United States standard design are equipped with wire-basket bunkers (fig. 1) fastened to nailing strips and placed about 2 inches from the side and end walls, the ice being supported by either a metal or heavy wooden grate placed a short distance from the bottom of the compartment. Most cars so equipped are provided with a solid insulated bulkhead having an opening of about 12 inches at the bottom and 14 inches at the top. The space between the ice receptacle and the car walls permits the free movement of air over almost all of the outer surface of the ice in the bunker.

The wire-basket type of bunker has proved its efficiency, but in the repeated attempts of car designers to improve the construction and efficiency of refrigerator cars another form of bunker, known as the divided wire-basket bunker (fig. 2), has been devised. It embraces the features of the United States standard type but in addition has a series of divisions, or flues, for the purpose of decreasing the ice capacity and increasing the meltage surface as the ice melts. The bunker is divided into four distinct sections by a main partition placed parallel to the longitudinal axis of the car, consisting of two sections of heavy wire netting 4 inches apart extending from top to bottom of the bunker and two smaller partitions placed parallel to the main partition but extending only about two-thirds the height of the bunker.

These secondary or intermediate partitions are of a construction similar to that of the main partition (fig. 3). They act as flues and allow air circulation around more of the ice than is the case with the United States standard type of recommended bunker construction.

RESULTS OF TEST TRIPS

As a means of determining the comparative performance of the two types of bunkers, two test trips were made, using two cars of identical construction for each test except that one was equipped with the wire-basket and the other with the divided wire-basket bunker. The first test was made in September, 1923, from the State of Washington to Chicago, Ill., and the second, from Florida to New York City, in June, 1924. Both tests were made possible only through the cooperation of the shippers, railroads, refrigerator-car lines, and receivers. The insulation in the cars was massed and was similar on all surfaces, and both cars were equipped with floor racks and wood roofs. The ice capacity of the divided wire-basket bunker car was 7,400 and that of the wire-basket bunker 10,400 pounds.

The cars were loaded with apples for the first and with oranges for the second test. Early on September 16, 1923, the cars were pre-iced at Othello, Wash., and loaded for the first test at White Bluff, Wash., and consigned to Chicago, Ill. The temperature of the apples loaded into the divided wire-basket bunker car was 78° F. and that of the fruit in the wire-basket bunker car 70.5° F. In the following discussion of both tests the divided wire-basket bunker car will be referred to as car A and the wire-basket bunker car as car B. The differences in the temperature of the apples in car A and car B were due to the fact that the fruit in car A was packed and loaded at once, while that in car B had been held in the packing-house storage room, which had been kept cool by sprinkling.

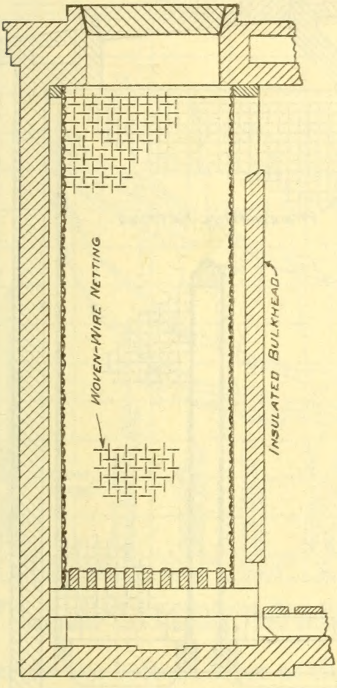

FIG. 1.—Cross section of standard wire-basket bunker

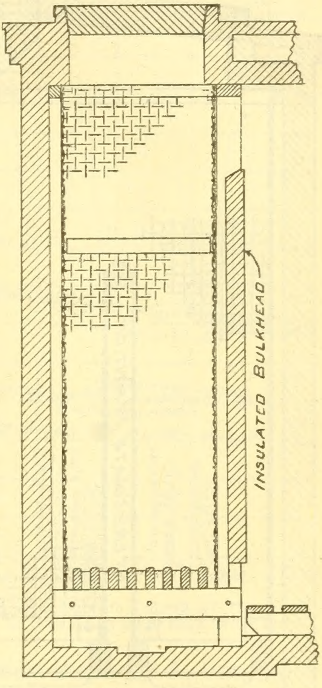

FIG. 2.—Cross section of divided wire-basket bunker

The first re-icing was made at Othello, Wash., on September 17 and the last at La Crosse, Wis., on September 24. Early in the morning of September 25 car B was diverted. Car A arrived in Chicago, at 6 a. m. the same day. The total quantity of ice supplied during the first test, including the pre-icing, was 20,680 pounds for car A and 24,740 pounds for car B, or a total saving of ice in favor of car A of 4,060 pounds, At the termination of this test the cars were released for regular road service and were not recalled until June, 1924, when they were sent to Florida to be tested the second time. On June 9 the cars were pre-iced at Haines City, Fla. The following day car A was loaded at Winterhaven and car B at Florence Villa, and both were consigned to New York. The temperature of the fruit placed in car A was 87° F. and that in car B 79.5°. The fruit in car A was freshly packed when loaded, but that in car B had been held in a packing house.

The first re-icing was at Lakeland, Fla., and the last at Potomac Yards, Va. The total quantity of ice supplied during this second test, including pre-icing, was 19,457 pounds for car A and 23,091 pounds for car B, or a total saving of 3,634 pounds for car A. The measured ice capacity of the bunker of car A is 3,100 pounds less than that of car B. In the first test, car A not only saved this difference but 960 pounds in addition, while in the second test it saved 534 pounds more than this difference.

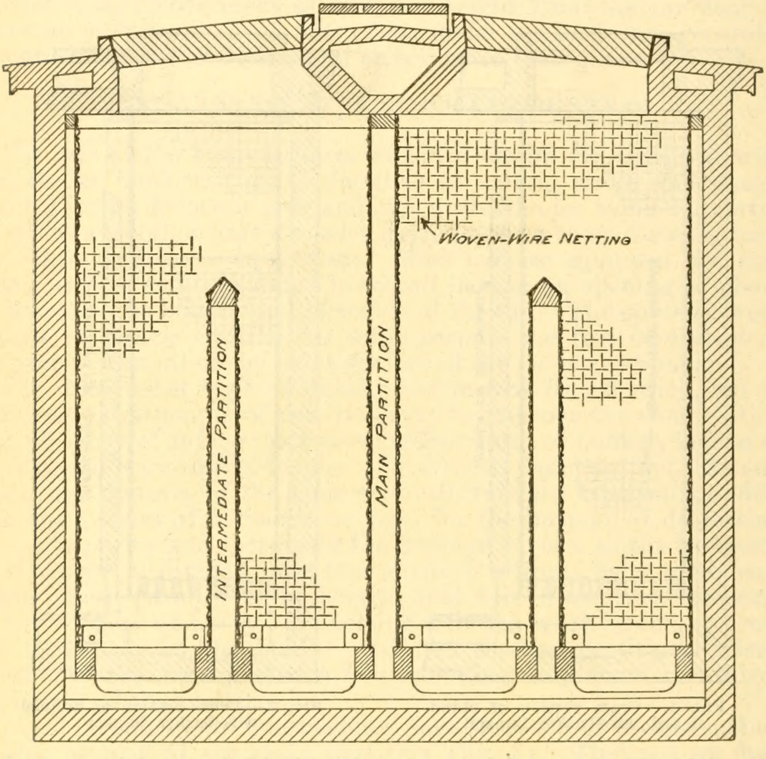

FIG. 3.—Front elevation of divided bunker of the woven-wire type, showing the main and the intermediate or secondary partitions

TEMPERATURES MAINTAINED

The basis for comparison of the temperatures maintained is the actual temperature of the fruit at the top and bottom layers of the load at the doorway, at the bunker, and in the middle layer at the quarter length of the cars. In addition, the average fruit temperatures of the top and bottom layers of the load are considered. The positions in the cars at which the temperatures were taken are the same in both tests and are in a vertical plane, equally dividing the car longitudinally. The initial readings shown on the accompanying charts (figs. 4 to 7), are the fruit temperatures at the time of loading.

Figure 4 compares the temperatures maintained in the top and bottom layers at the doorway and bunker. Inasmuch as there is not so large a difference between the top and bottom layers at the doorway of car A as between the top and bottom layers of car B, the record is in favor of car A. Car B registered a temperature 1 degree lower on the bottom layer at the doorway than car A, but car A was cooler at the top layer by about 2 degrees.

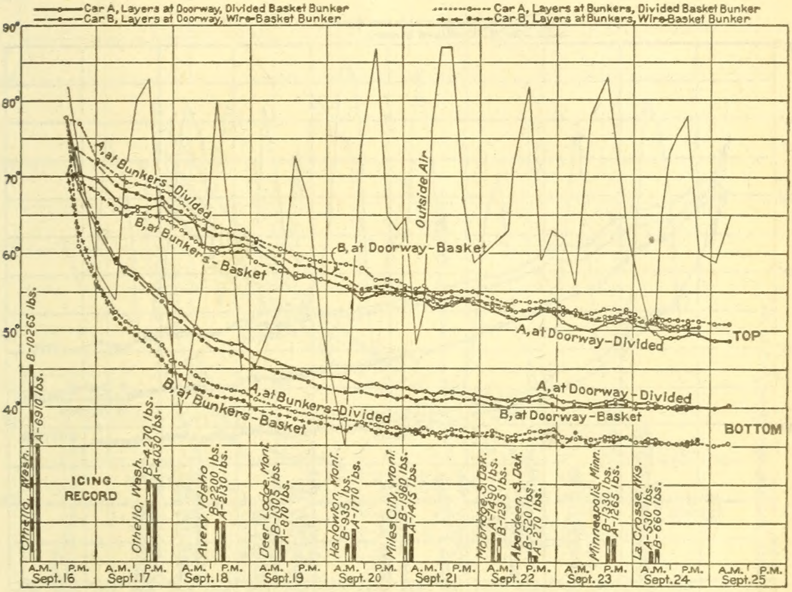

FIG. 4.—Fruit temperatures, first test, at top and bottom layers of the load at doorway and bunkers. The order of cars is that in which they were iced

At the top and bottom layers at the bunker, car A maintained a slightly higher temperature than car B; however, the greatest difference was noted in the top layer during the first five days. A greater fall occurred in car A by midnight of the first day than in car B, but the latter fell slightly lower than car A and maintained a gain of approximately 2 degrees throughout the trip.

Attention must be called to the initial fruit temperature at loading. The temperature of the fruit loaded in car A averaged 78° F. and that in car B 70.5°. Consequently, the fruit in car B had the advantage of being 7.5 degrees cooler at the beginning of the test. Had this initial temperature been the same, then in all probability the two cars would have shown the same temperature at the top layer, but car B would have been approximately 5 or 6 degrees higher at the bottom layer during the first few days of the trip.

Again, the difference in temperatures between the top and bottom layers at the bunkers is generally greater than between the top and bottom positions in other parts of refrigerator cars. This difference is more marked where the air circulation becomes choked through poor construction, faulty loading, or the shifting of the load. When the air is blocked at the bottom of the bunker the packages adjacent to it receive the full benefit of the cold air, while those at the top of the load remain comparatively warmer. The type of construction at this point plays an important part in air circulation within the car.

Figure 5 shows the record of the temperatures maintained at the middle layer, quarter length. The curves for cars A and B are practically the same, but if the initial fruit temperatures had been the same, that for car A might have been slightly lower. Car A, however, records a more rapid fall in temperature than car B up to midnight of the first day and overcomes the disadvantage of the warmer fruit with which it was loaded.

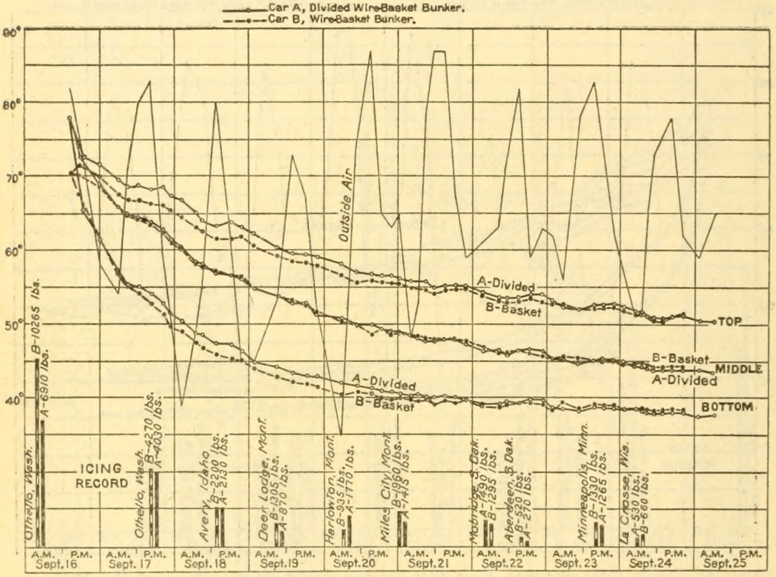

FIG. 5.—Average fruit temperatures, first test, at top and bottom layers and fruit temperature at middle layers of the load at the quarter length

To understand fully the actual work done in cooling the load, consideration should be given not only to the temperatures maintained within the car at various positions but also to the average temperature of the lading. Although this temperature is not so important as it might appear, it aids in determining the actual performance, particularly if the individual temperatures are given due weight. The average temperatures for the top and bottom layers are shown in Figure 5. The curves show a little difference, but the effect of the higher initial temperatures is readily seen. It is reasonable to make allowance for this factor by assuming that in so far as the average temperatures are concerned car A and car B are equal in performance.

Figure 6 shows the fruit temperatures maintained at the bunker and doorway positions on the top and bottom layers in the second test. The temperatures in car A at the bunker were slightly higher in both the top and bottom positions than those in car B, although the initial fruit temperature was 7.5 degrees higher than in car B. The cars show a parallel and abrupt drop in temperature from the time of loading until midnight of the first day, when the drop begins to steady and the curve flattens out. The difference between cars A and B at 6 a. m. of the second day was 7 degrees, approximately the same as that between the initial fruit temperatures, and very slowly diminished, until on the last day the temperatures were practically the same. At the top position a more gradual cooling is seen, but from the beginning of the test until about noon of the third day there remained a difference of 7 degrees. This difference diminished slowly but remained marked at the end of the trip. Both cars had practically the same temperature until the last reading, when car A showed a slightly lower temperature. At the top doorway position car B showed an average about 1 degree lower than car A. In the bottom position at the beginning of the trip the fall in temperature was sharp and may be favorably compared with the drop in the

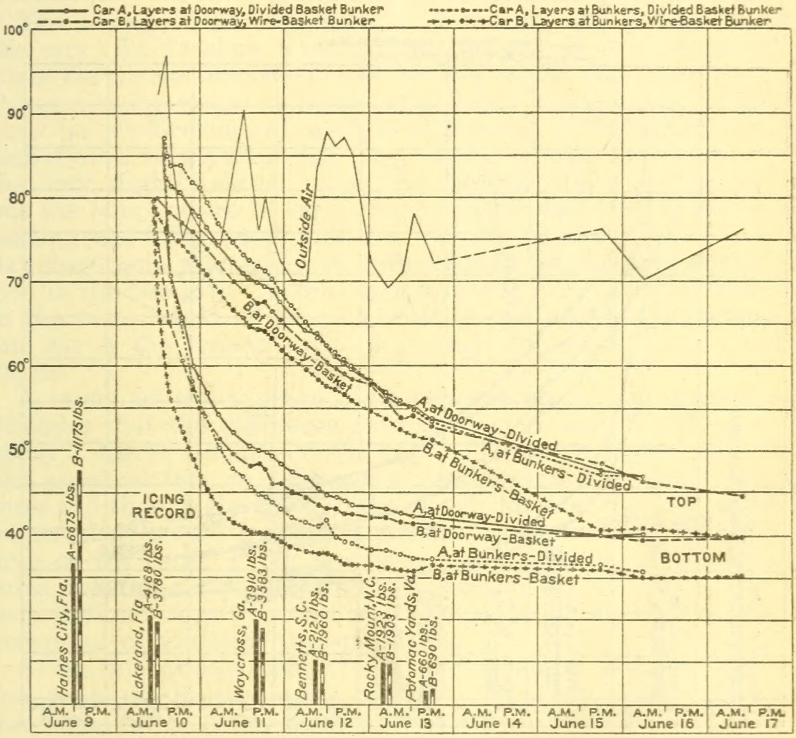

FIG. 6.—Fruit temperatures, second test, at top and bottom layers of the load at doorway and bunkers

bottom position at the bunker. Car B registered the lowest temperature throughout the trip. The temperature differences are so slight, however, that when the initial fruit temperatures are considered the performance of the cars may be regarded as equal.

Figure 7 shows the temperatures recorded for the middle layer at the quarter length and the average fruit temperatures of the top and bottom layer of the load in the second test. The middle layer at the quarter length is particularly hard to refrigerate, because of the difficulty in getting adequate air circulation at this point. At the beginning of the trip car A was about 3 degrees higher than car B at this position. This difference gradually diminished, however, until the early morning of the third day, when the temperature of the cars was practically the same at this point. At the end of the trip the temperature of this position in the load had been reduced in car A 45 and in car B 37 degrees from the time of loading to 8 p. m. on the sixth day, a period of approximately 5¼ days. The cars may be regarded as equal for performance at this position, consideration, of course, being given car A because of the warmer fruit with which it was loaded. Comparing the curves in Figure 6 it will be seen that the cooling of the load proceeded rapidly in all cases. At the bottom bunker position the temperatures were below 40° F. approximately 48 hours after loading. In the same period at the bottom doorway position they were below 45° F. During this time the flattening of the curves are apparent and still indicate

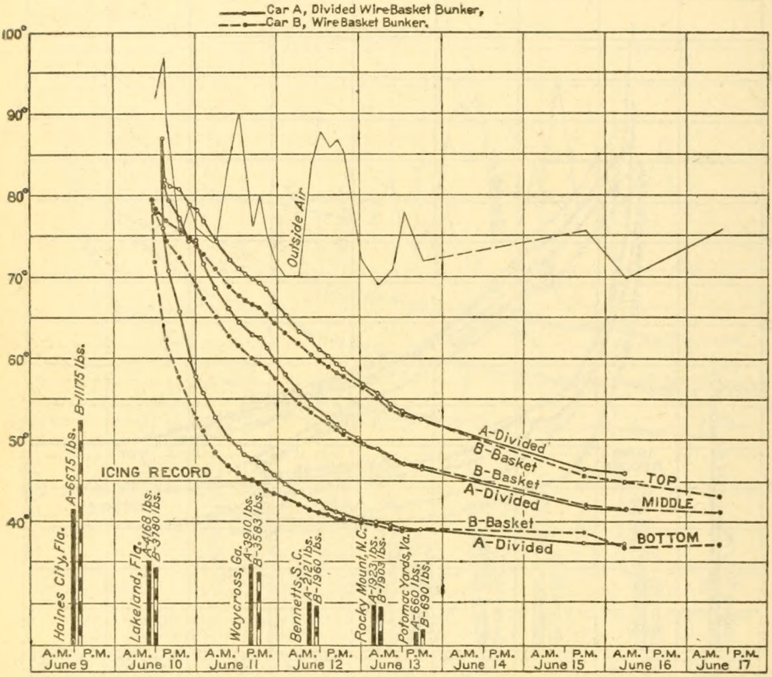

FIG. 7.—Average fruit temperatures, second test, at top and bottom layers and fruit temperature at middle layers of the load at the quarter length

the lowering temperature. If a comparison of the temperatures at the top bunker and top doorway positions is made, it will be seen that there is but a slight difference, those at the doorway falling still within the temperatures at the bunker. There is, however, a slight difference in the range of temperatures at the top positions. Those in car A are practically the same as those in car B at the doorway, which is only 1 degree lower, while at the bunker there appears to be an equal range between the cars, which would be readily seen if it were possible to superimpose the curves shown in Figure 6.

COMPARATIVE STUDY OF TEMPERATURES

The average fruit temperatures of the top and bottom layers of the cars (fig. 7) show a marked similarity. If it were possible to place the initial temperature at loading at the same starting point, this similarity would be more marked and would in all probability show the performance of car A to be superior to that of car B. Both cars show a very abrupt fall from the initial temperature, car B being very slightly slower in cooling its load in the bottom position, but the temperature in car A lagged somewhat and 24 hours after loading was 2 degrees higher than car B. At midnight of the third day there were practically no differences in temperature at this position in the two cars. At the top positions a similar relation was found in the same length of time. Car B showed the lower temperature and car A the higher, with an average difference of only about 1 degree.

A study of the average fruit temperature of the middle layer discloses that the difference between cars A and B averaged only about 1 degree throughout the trip. The rather remarkable fact is also apparent that no difference exists between the average temperatures and those maintained in the middle layer at the quarter length, which alone would indicate a striking uniformity in the performance of the cars. From the foregoing discussion of the temperatures maintained by the cars on the second trip it would seem that such differences as exist are so slight as to be negligible from the viewpoint of practical transportation.

At the time of unloading at market destination a careful inspection was made of the test boxes of fruit. Only one decayed specimen was found in car A and no decay whatever in car B.

The efficiency of a refrigerated car is largely determined by its ability to reduce quickly the temperature of a warm load to a relatively low point and to maintain it until the arrival of the car at its destination. Not only must the car be rated for efficiency upon the temperature maintained within it but also upon the comparative quantity of ice it melts in producing these temperatures. Refrigeration can not be obtained without ice meltage, but it is not necessarily true that the car which melts the most ice is the most efficient. However, if the car is in good condition and the temperature of the commodity at the time of loading is taken into account, ice meltage will be some indication of the comparative performance of the car.

In the two tests under discussion the car equipped with the divided wire-basket bunker maintained temperatures equivalent to those in the car having the United States standard type of wire basket. Not only does this demonstrate its efficiency in cooling, but it also shows its economic value in its lesser ice requirement. In the first test, car A was supplied with 4,060 pounds and in the second test with 3,634 pounds of ice less than car B, which may be considered a direct saving in ice meltage and a saving not made at the expense of the cooling efficiency of the car.

SUMMARY

The United States standard specifications for refrigerator cars recommend wire-basket bunkers. To increase the efficiency of these bunkers, a divided wire-basket type has been devised which embraces the features of the United States standard wire-basket bunker but has less ice capacity and increases the meltage surface as the ice melts.

To test the efficiency of this new type of bunker two tests were made in which two cars were used, one being equipped with the United States standard wire-basket bunker and the other with the divided wire-basket bunker.

The car having the divided wire basket maintained temperatures equal to those maintained by a car of exactly the same construction except that it was equipped with a United States standard wire-basket bunker of larger ice capacity.

This car proved to be economical in ice consumption, requiring 4,060 pounds less ice in the first test and 3,634 pounds less in the second test.

This saving in ice was not made at the expense of the cooling efficiency of the car.

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